# Remote Intervention Tower Elimination System

## Topical Report

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Authors: Dave Murnane
Renauld Washington

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Submitted By:
Oceaneering Intl.
Advanced Technologies
Remote Intervention
501 Prince George's Blvd.
Upper Marlboro, MD

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# Abstract

This Topical Report is presented to satisfy reporting requirements in the Statement of work section J.5 page 120 per Department of Energy contract DE-AC26-01NT41093. The project does not contain any imperial research data. This reports describes the assembly of Commercial of the shelf (COTS) items configured in a unique manner to represent new and innovative technology in the service of size reduction and material handling at DOE sites, to assist in the D&D effort currently underway at the designated DOE Facilities.

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# 1 Executive Summary

The size reduction and remote handling program is a government-funded effort to demonstrate technologies for dispositioning transuranic (RH-TRU) waste inventory at Hanford. A current forecast indicates that more than 25,000 cubic meters of low level waste (LLW), long length equipment (LLE) (1200 containers) and 1100 cubic meters of TRU LLE will require processing and disposal. In addition to this, there is a forecasted non-LLE volume of 3800 cubic meters of remote handled (RH) waste and 1700 cubic meters of RH-TRU waste as well as 1700 cubic meters of failed equipment presently stored in the PUREX tunnels that may need to be removed and processed for disposal.

The first waste stream components to be tackled under this program are two (2) PUREX towers located on the canyon deck of T-plant. While these towers are the initial items of the long-length and oversized RH-TRU waste inventory to be size reduced, any equipment and processes procured under this program are expected to be generally applicable to many items. Other systems to be size reduced later include process vessels and significant amounts of piping. The towers are representative of the materials of construction, contamination levels, and component sizes that comprise many other items in the long-length and oversized RH-TRU waste inventory.

The goal of this program is to demonstrate (and potentially deploy) remotely controlled equipment to process large equipment in a safe and effective manner. Currently, large equipment is size reduced and handled using personnel in close proximity to the equipment. There are several ways this size reduction process could be improved. The objectives of the program are to:

- Reduce the number of personnel required for the tasks;
- Reduce worker exposure;
- Reduce the volume of the material that is disposed of as TRU waste by improved packing factors;
- Utilize commercially available equipment so as to reduce the need for specially developed equipment;
- Minimize secondary waste generation;
- Limit the potential for the spread of contamination.

Oceaneering was awarded contract DE-AC26-OINT41093 Phase I by NETL to demonstrate the ability to remotely size reduce and handle large equipment using its Remote Intervention Tower Elimination System (RITES). Phase I, "Proof of Principle Cold Demonstration," demonstrated the ability of OII to deliver a mobile, remotely controlled, robotic vehicle capable of cutting and size reducing a steel structure similar to the PUREX T-L2 and T-J4 towers.

Specific Phase I objectives included deployment of the robot into the simulated work area with limited personnel entry, demonstration of the robot to be maneuvering within a space similar to the work area in the T-Plant canyon, remote operation of the robot's onboard tool(s) to size reduce a tower mock up, demonstration of a crane deployed electromagnetic to secure cut pieces and transport them for characterization and packaging, and demonstration of the throughput efficiency and overall safety of the process.

This Phase I of the size reduction and remote handling program was successfully completed. Oceaneering demonstrated that this work can be accomplished in an effective manner with significant improvements in worker safety. Integration of these technologies provided a synergistic effect.

Although large component size reduction was demonstrated to be viable, additional enhancement would improve operational effectiveness (such as quantity and placement of cameras, use of an electric robotic arm, etc.).

This system has the flexibility to be utilized for other tasks including remote radiation monitoring/characterization, remote material sorting and packaging, and remote inspections.

# 2 Introduction

The Oceaneering Remote Intervention Tower Elimination System (RITES) utilizes an assembly of commercially available components to produce a remotely operated size reduction process. Emphasis is placed on flexibility and ease of operation. Central to the system is the mobile robotic work platform that will maneuver easily and employ its plasma arc cutting torch to size reduce the tower structures. To minimize airborne contamination, a crane mounted ventilation hood is suspended over the cutting area. This hood will also use an electromagnet to transport cut pieces to the waste boxes. The system requires no temporary structures to be erected, no modifications of existing canyon equipment and no special utility services. It minimizes the need for personnel entry into hazardous work zones and produces no secondary waste.

Oceaneering's approach provides a stable, compact, easily maneuverable platform that is simple to deploy and does not require a complex interface with a computer system. The Telerobotic crawler is tough and field proven. (The crawler used in Phase I was originally fabricated and deployed with a gamma camera to perform characterization of a commercial nuclear facility undergoing D&S. If repairs are required, components are bolt on packages. The "RITES" approach leaves the overhead crane free to perform lifting duties. The baseline system utilizes Commercial off the Shelf (COTS) items in a unique configuration. This system consists of four subsystems, each designed for ease of operation and maintenance. The use of field proven components increases the system's reliability.

Plasma arc torches are an efficient means of cutting the tower and would provide high throughput. It does not require change out of blades, as mechanical devices would, and irregular surfaces or difficult cutting angles would not hinder it.

Oceaneering's RITES concept offers a highly versatile approach, which minimizes or eliminates direct human intervention in the work area during operations. Personnel entry into the work area is not anticipated during size reduction operations. All equipment is tethered and, should repairs be necessary, equipment can be retrieved with the overhead crane and brought to the gallery area for repairs.

The system (Shown in Figures 1.1, 1.2, and 1.3) is operated by placing the electrically powered, remotely operated, telerobotic, tracked vehicle system (24"W x 46"Lx38"H), (hereafter referred to as "the crawler") in the canyon utilizing the existing overhead crane. It is equipped with a pan and tilt camera system; extendable platform, positioning system, and plasma arc, cutting torch, with remote controlled device. The system is housed in a deployment cage. The cage provides a carrying space for the crawler, a power source for the Plasma Arc Cutting Torch, a Tether Management System (TMS), and Controls and Power Junction Boxes for the various functions of the system. The system is operable from outside the canyon by an operator controlling the Crawler and TMS remotely, through an attached power and control, tether and umbilical. The tether allows the crawler to travel 22 feet from the cage. The vehicle will be maneuvered along side the tower and will position its cutting torch to size reduce the tower into approximately 40" lengths.

No special transportation will be required. The equipment is relatively lightweight and compact. Transportation to site requires one small capacity truck. Unloading would require access to a loading dock or availability of a small fork truck. Staging of equipment for deployment can be accomplished with a pallet jack.

Upon completion of hot work, the vehicle can be taken to a decontamination area and decontaminated with high pressure spray wash, CO2 blasting or any number of conventional decontamination methods. The vehicle can easily be disassembled for decontamination of individual components. Vehicle cables can, likewise be decontaminated. The worst case scenario would be that no equipment, introduced into the contaminated work area, could be successfully decontaminated. In that event, all equipment would fit into one (1) standard waste box.

There are no special utility requirements associated with the equipment.

Figure 1.1. RITES System Elevation (DM302807 Sheet 1)

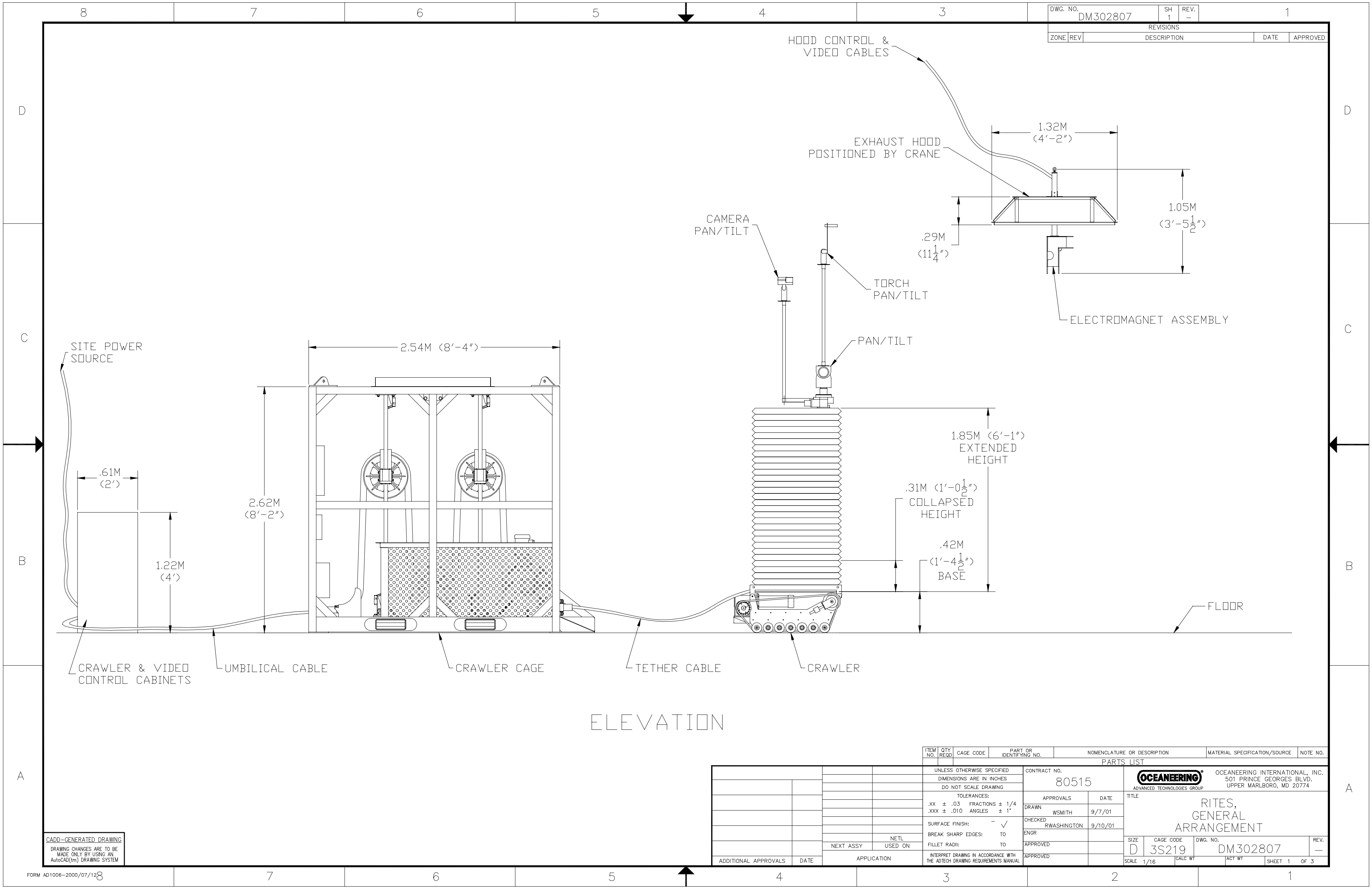


Figure 1.2 RITES System Plan View (DM 302807sheet 2)

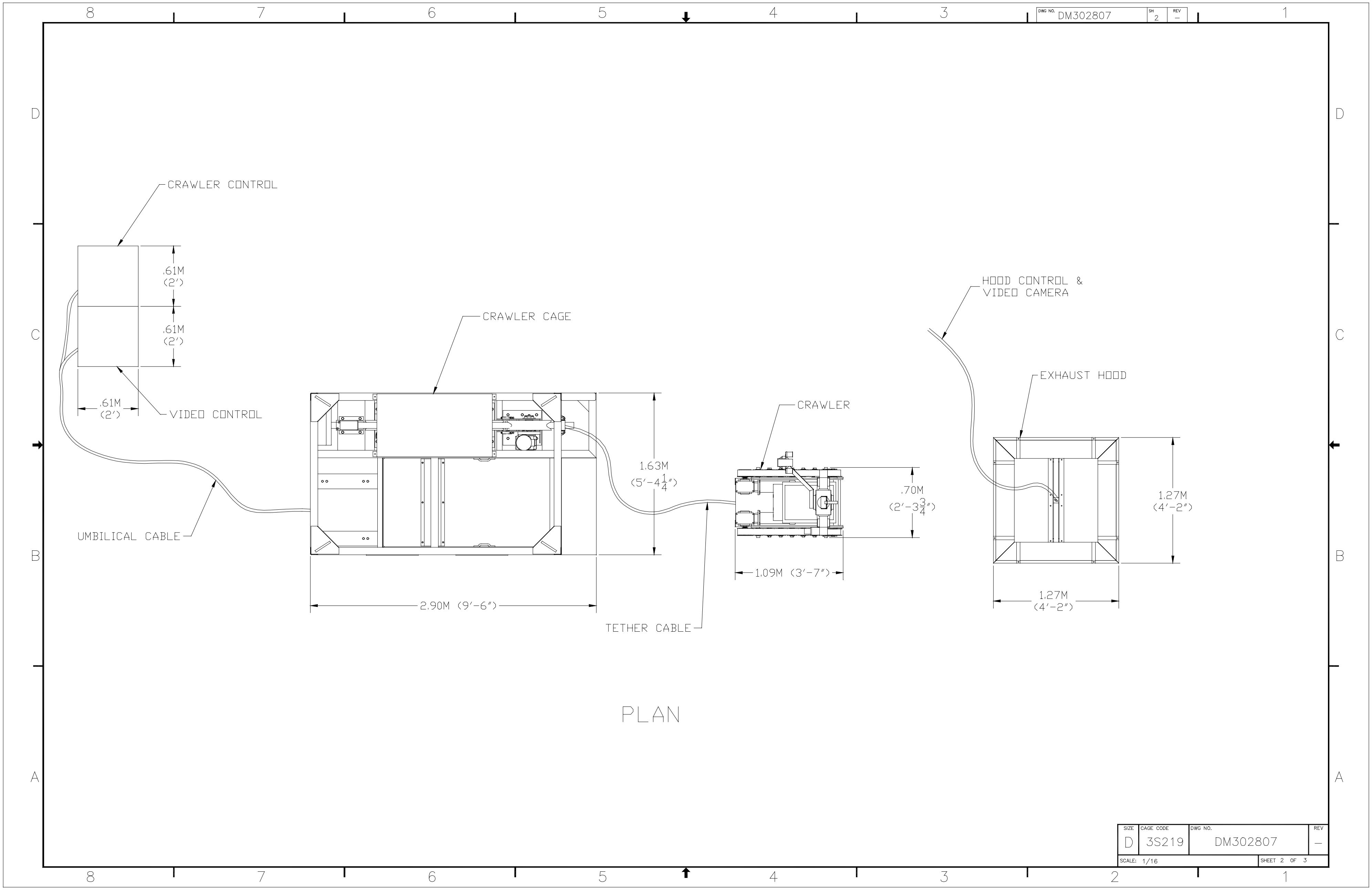
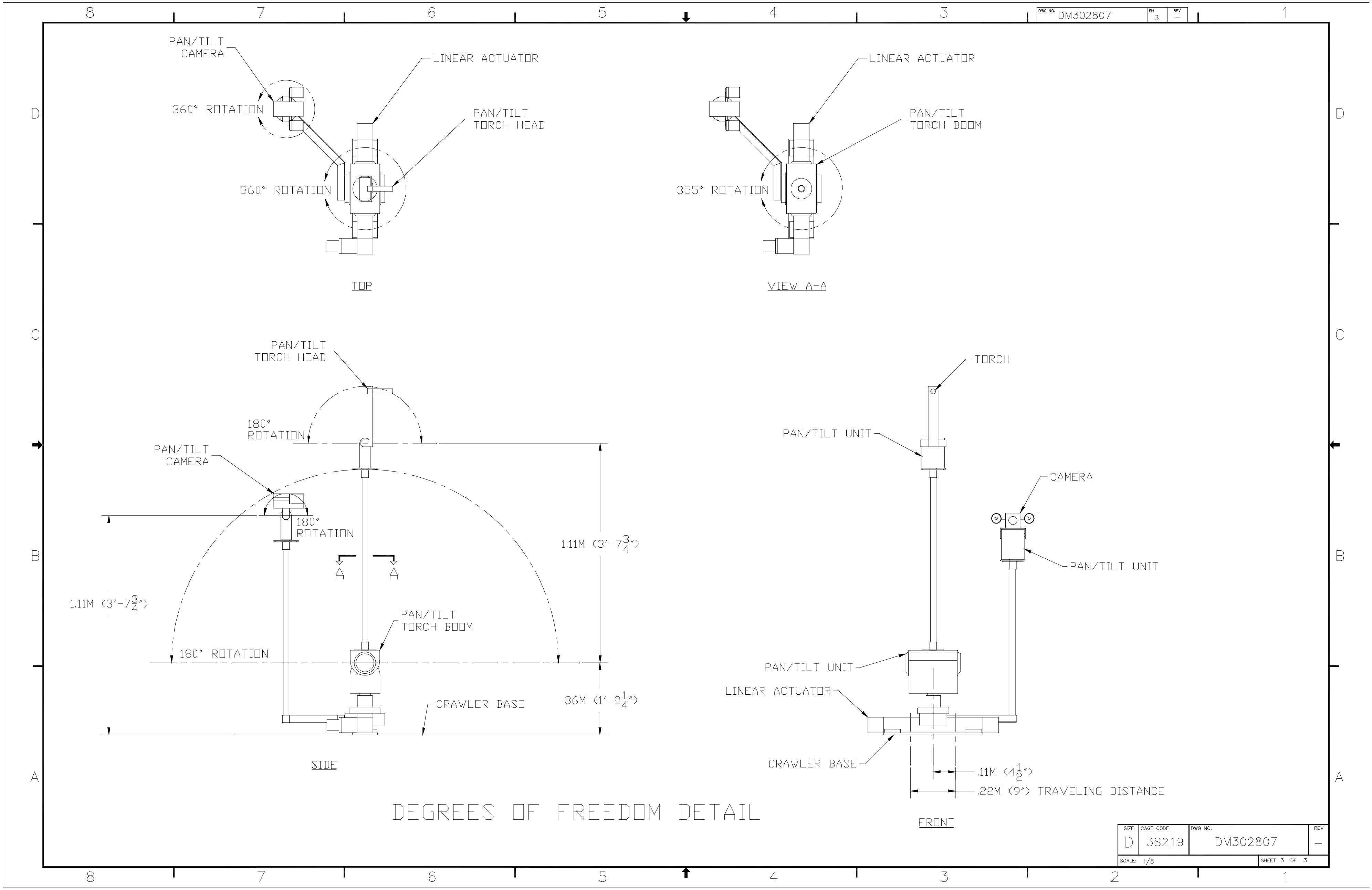


Figure 1.3 RITES System Range of Motion (DM 302807 sheet 3)

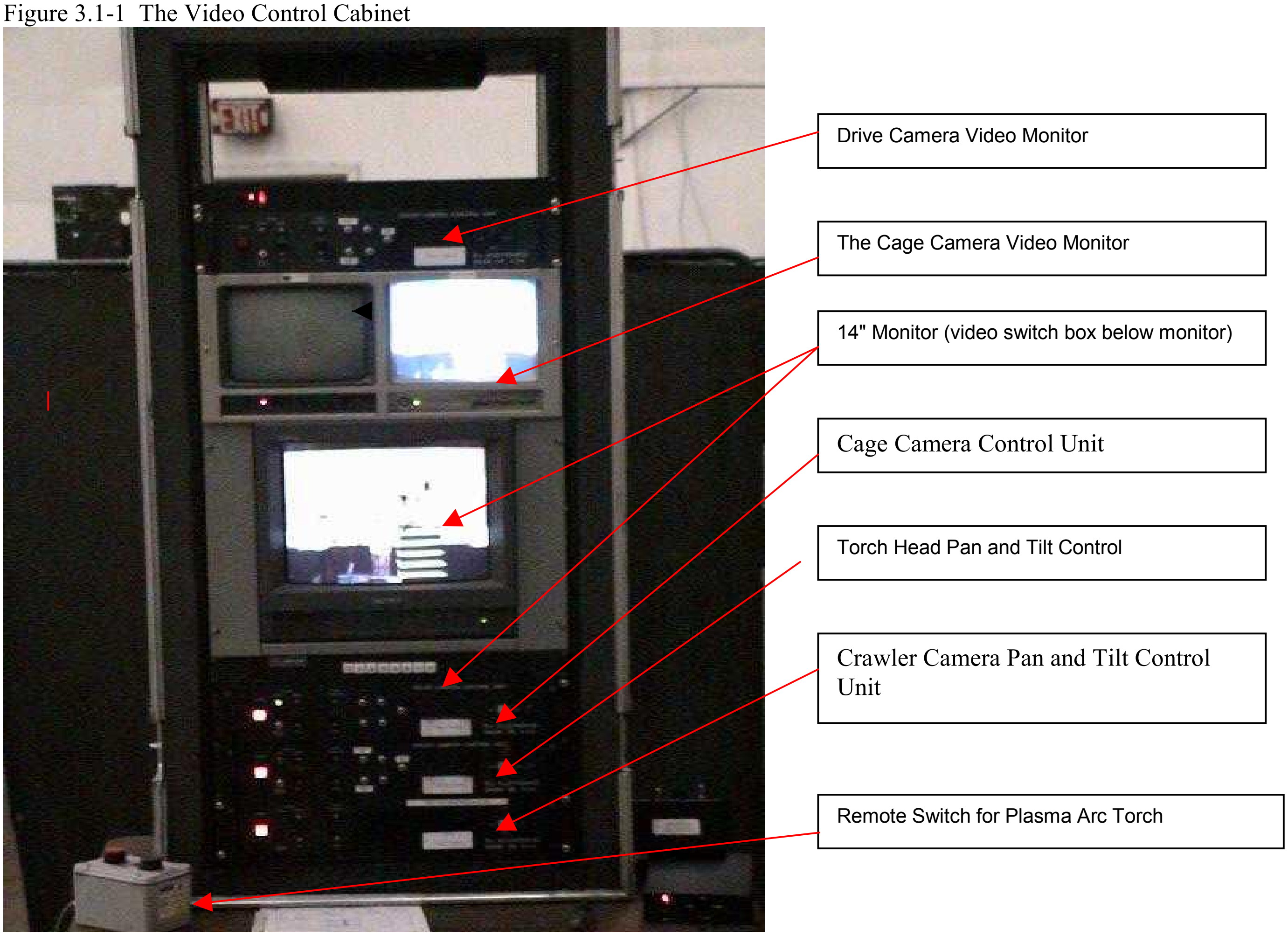


# 3 SYSTEM DESCRIPTION

## 3.1 Operator Control Station

The control station is comprised of two cabinets; (hereafter referred to as the Video Control and Crawler Control Cabinets), a Slide Control Pendant, Crawler Pan and Tilt Control, Tether Management System Control, a remote switch for the Plasma Arc cutting torch, and the Torch Boom pan and tilt control unit.

Figure 3.1-1 The Video Control Cabinet




The Video Control Cabinet

The Video Control Cabinet contains the Cage Camera Control unit, the Crawler Camera Control unit, the video monitors and Torch Head Pan and Tilt Control unit, and the video monitor switcher (Pictured above in 3.1-1.)

Cage Camera Control unit

The Cage Camera Control unit has auto/manual focus, and exposure; individual controls for pan and tilt and variable speed regulators for each degree of freedom

Torch Boom Pan and Tilt Control

The Torch and Pan and Tilt Control Pendant controls the Pan and tilt unit located at the base of the Torch Boom. The Unit contains controls for the two degrees of freedom.

Video monitors

The Video control station contains three monitors: two (2) 9” monitors, and a 14” color monitor.
The 14 “ monitor will serve as the main operator interface for operations, the (9”monitors will provide alternative views and can be switched between the Cage camera, the hood camera and the crawler drive camera by the manual switch station located between the 9” monitors and the 14 “ monitor).

Torch Head Pan and Tilt Control unit

The Torch Head Pan and Tilt Control unit controls the motion of the Pan and Tilt located at the top of the Torch Boom, the unit contains controls and power for the two degrees of freedom.

Crawler Camera Pan and Tilt Control unit

The Crawler Camera Pan and Tilt Control houses the controls and power for the motion, and function of the camera, located on the Crawler Camera Boom shown in figure 3.1-2

The Linear Slide Control Pendant

The Linear Slide Control Pendant is a freestanding pendant, which controls a variable speed regulator and a forward and reverse toggle switch.

The Tether Management System Control

The Tether Management System control is a free-floating foot pedal control device located on the floor of the control station. The control device has two separate pedals, one for reeling out the tether and one for reeling in the tether.

Remote Switch For Plasma Arc Torch

The Plasma Arc Remote Switch is a free standing push button pendant, which allows the operator to start and stop the torch operation.

The Crawler Control Cabinet

The Crawler controls cabinet houses the Power Distribution Unit (PDU) for the crawler, the power source for the drive camera, Individual controls for the scissor lifts and individual controls for the crawler.

### 3.2 Crawler Assembly

The Crawler Assembly consists of several components. An electrically powered, remotely operated crawler, two (2) scissor-lifts, a camera boom assembly, a torch boom assembly, a linear slide and a drive camera (shown below in figure 3.2.-1).

Figure 3.2-1

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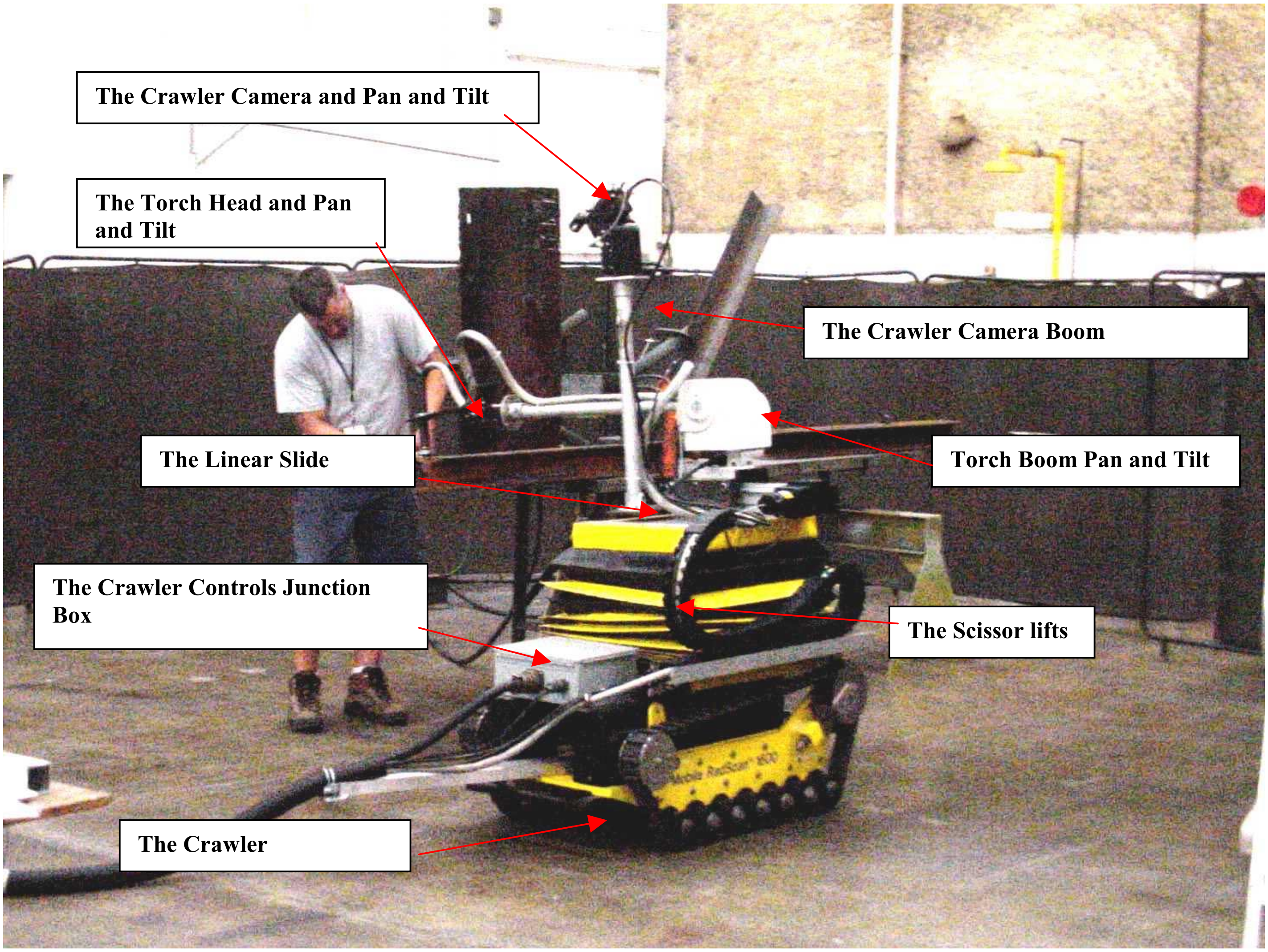



The Crawler

The crawler is electrically powered, and remotely controlled. The controls are run through the crawler junction box, to the tether, and transitioned to the cage-umbilical via the controls and power junction box and terminated at the crawler control cabinet. The controls consist of left and right toggle switches for forward and reverse motion and individual speed regulators.

### The Scissor Lifts

The scissor lifts are Commercial Off The Shelf (COTS) items. The lifts are mounted mechanically in series. Each lift employs a self-contained hydraulic system actuated by an electric pump. The controls and power for the lift pumps are run through the crawler junction box, to the tether, and transitioned to the cage-umbilical via the controls and power junction box and terminated at the crawler control cabinet.  See Figures 3.2-2 and 3.2-3.

### The Linear Slide

The linear slide is a COTS unit, which is electrically powered and controlled by a remote pendant, located at the control station. The control and power are run through the tether, transitioned at the cage and terminated at the control station. The linear slide is powered by a reversible, variable speed electric motor and is mounted parallel, and on the surface of the top scissor lift table towards the front of the crawler, to provide lateral motion of the Torch boom.

### The Camera Boom Assembly

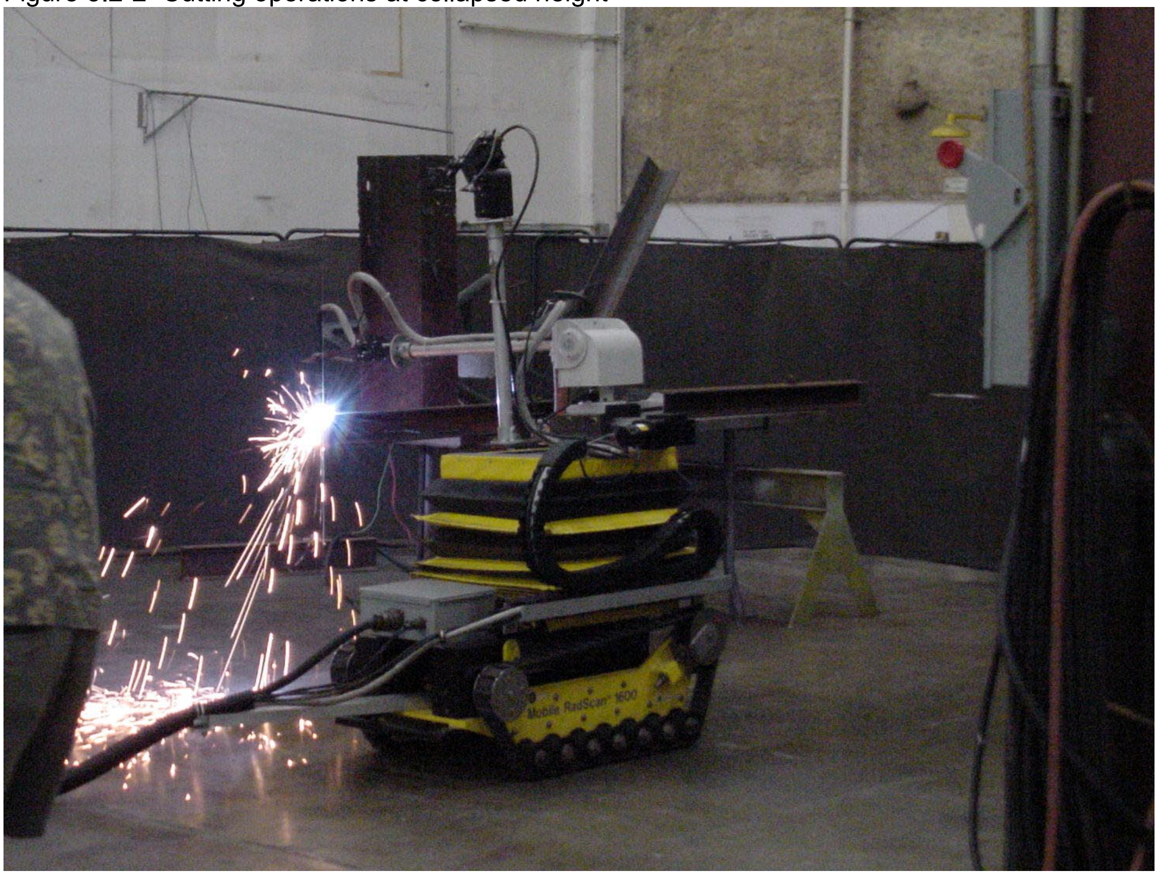
The Camera Boom Assembly consists of a camera, a static boom and Pan and Tilt (P&T) system.  The Camera is capable of 72:1 Zoom, and utilizes S-video signal transmission. The camera has two (2) miniature in-air lights mounted to each side of the lens. The P&T unit is capable of 360º of rotation about the boom axis and 180º vertical motion perpendicular to the axis of rotation. The camera and P&T are designed for environmental applications. The camera and P&T are electrically powered and controlled via cables that are run from the assembly, through the crawler junction box to the tether, transitioned at the cage controls and power junction box to the cage umbilical cables and terminated at the video control cabinet. The boom assembly is mounted to the linear slide by a bracket which positions the Camera Boom, behind and orthogonal to the Torch Boom Assembly, to provide optimum vision of the torch tip.

### The Torch Boom Assembly

The Torch Boom Assembly consists of the Torch Head, a compliance bracket, a Mechanical standoff and two (2) P&T units. The Torch Head is a Commercial off the shelf, Plasma Arc Cutting Torch, that is capable of currents up to 100 amps. The distance from the torch head to the cutting surface is maintained by a mechanical standoff that is attached to the torch head. The torch is mounted to a compliance bracket that allows for the necessary flexibility needed to allow the torch head to travel the cutting surface with a minimum of binding or hold points. The compliance bracket is mounted to a P&T. The P&T unit is mounted to a static boom, which is mounted to a P&T unit. This assembly is then mounted to the Linear Slide.

Figure 3.2-2 Cutting operations at 90% Extension

Figure 3.2-2 Cutting operations at collapsed height



The Drive Camera

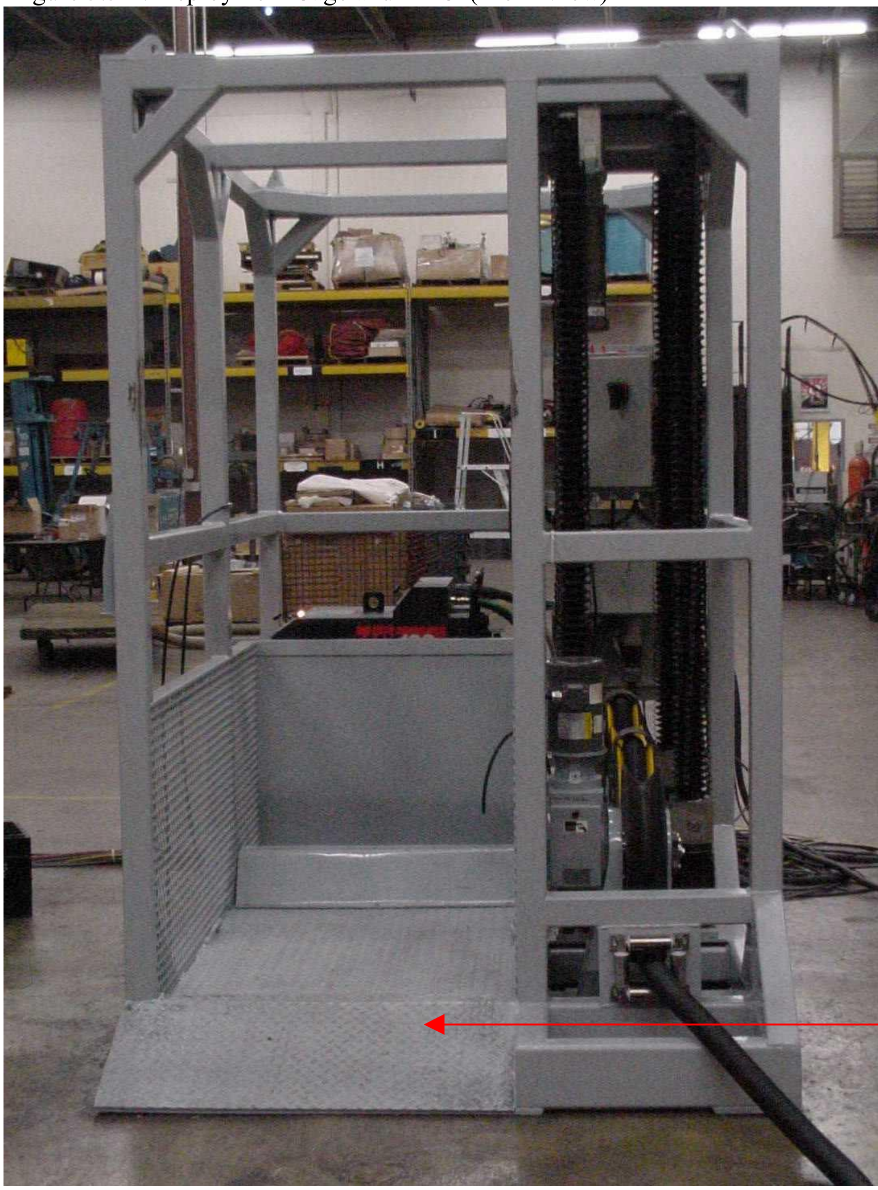
The drive camera is fixed and mounted to the crawler in front of the vehicle between the tracks.

### *3.3 Deployment Cage*

The Cage (shown in Figures 3.3-1, 3.3-2, and 3.3-3) protects the crawler during site ingress and egress. The Cage incorporates a Tether Management System (TMS) to locally manage the paying in and out of the crawler system cables and hoses. The Cage is designed to withstand multiple deployments around the work piece or pieces while providing a high level of protection from swing hazards during the deployment. The deployment of the cage is accomplished by using the site-supplied crane and rigging.

The Cage is an assembly that serves as the controls and power interface between the operator control station and the crawler. The Cage is designed to house the Crawler, the power source for the Plasma Arc Cutting Torch, the Cage PDU, the TMS and the controls and power junction boxes.

Figure 3.3-1. Deployment Cage and TMS  (Front View)



Crawler Staging Area

Figure 3.3-2 Side View of Deployment Cage and TMS

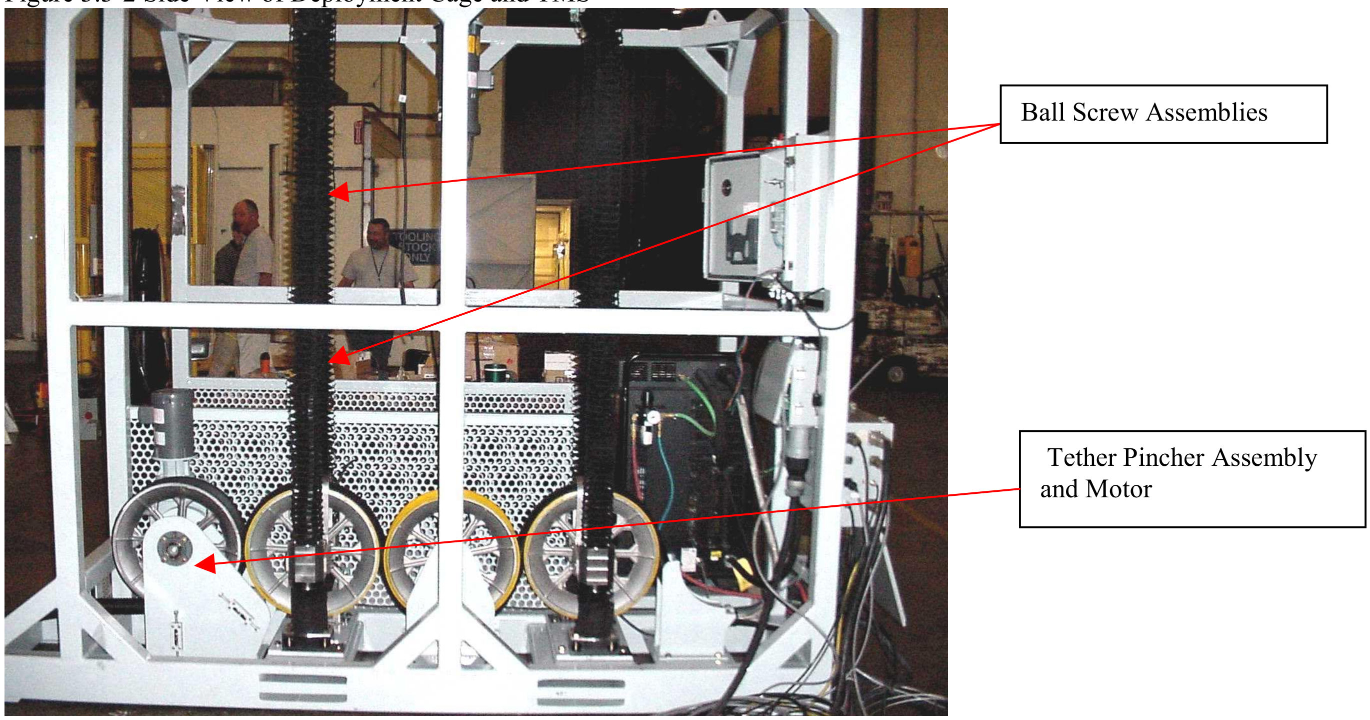
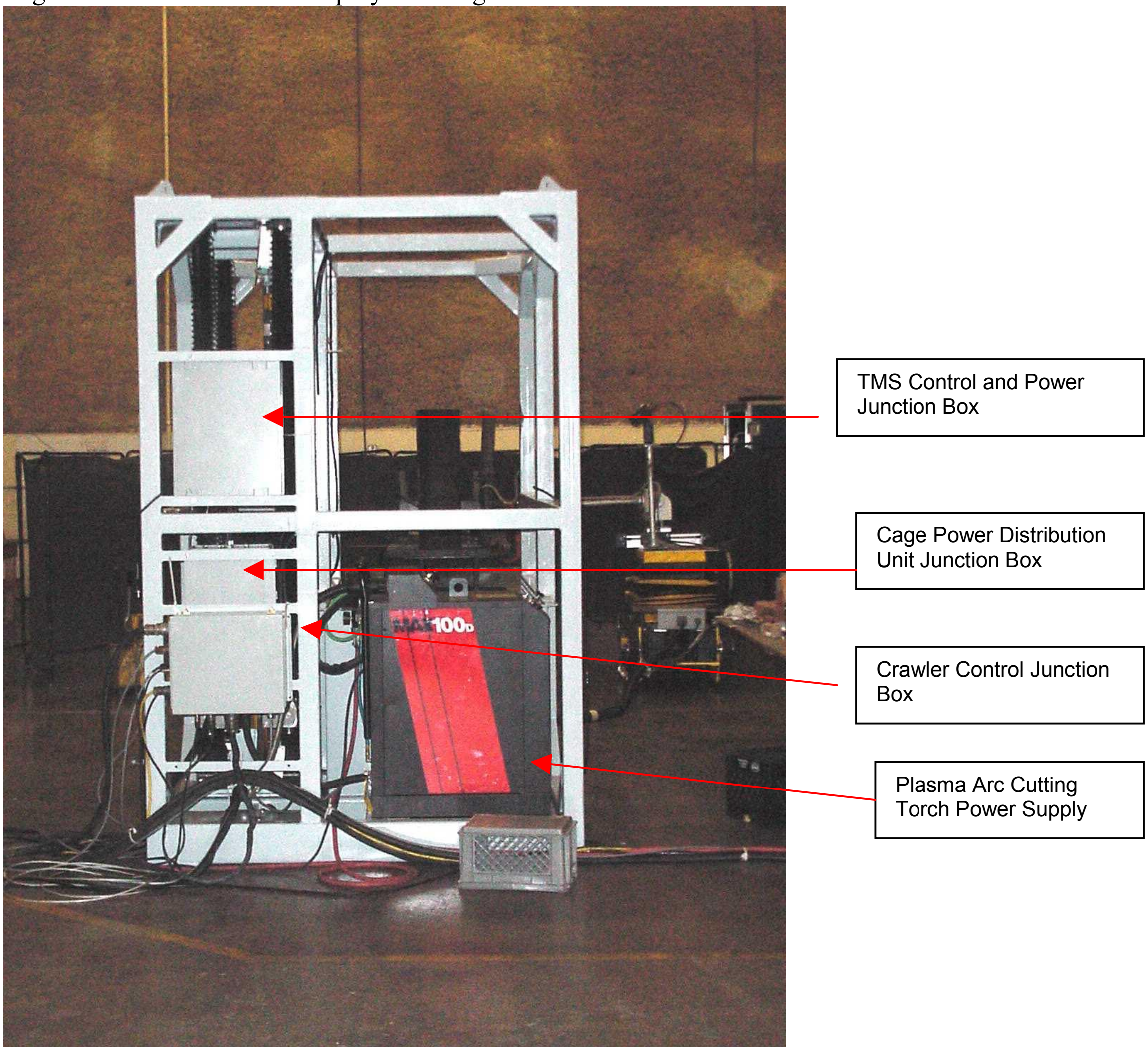


Figure 3.3-3 Rear View of Deployment Cage




The Plasma Arc Cutting Torch power supply

The power supply provides the necessary power and air to the torch head. The voltage requirements to power the source is 480 VAC

The TMS

The TMS is located inside the Deployment Cage (as shown in figure 4.1.5). The system utilizes four sheaves and a ball screw assembly consisting of four Ball Screws with associated hardware, a gear-pulley system located at the top of the Deployment Cage, and assisted by a pinch roller located at the entrance of the TMS. The Pinch roller assembly and the Belt drive system at the top of the cage are synchronized by two variable speed motor drives located in the Controls and Power Junction Box. This configuration allows the safe and effective handling of the multiple bundled hoses and cables that supply the crawler system, without the expense and complexity of a multi-service slip-ring.

The TMS Control and Power Junction Box

The Controls and Power Junction box houses the drives for the Tether Management System and the Limit switches for the tether sheaves and the MCC for the System.

The Cage PDU

The Cage PDU serves as the power distribution point for the systems housed by the Cage.

Crawler Controls Junction Box

The Crawler Controls Junction Box effectively transitions the control and power from the Cage umbilical to the Tether for the Crawler. Terminal blocks and Environmental Connectors make the transitions effective and maintenance friendly.

## 3.4 Fume Hood and Electromagnet Assembly

The Fume Hood

The Fume hood is a work in progress that crosses project Phase I and Phase II. The intention of the hood in its final configuration is to extract the associated fumes from the enclosed area as the cutting operations are being performed. The filtration system and the integration of that filtration system will be addressed in the phase two portion of the project The Hood acts as a platform for the Electromagnet assembly. The hood also houses a fixed camera that is integrated into the video control cabinet

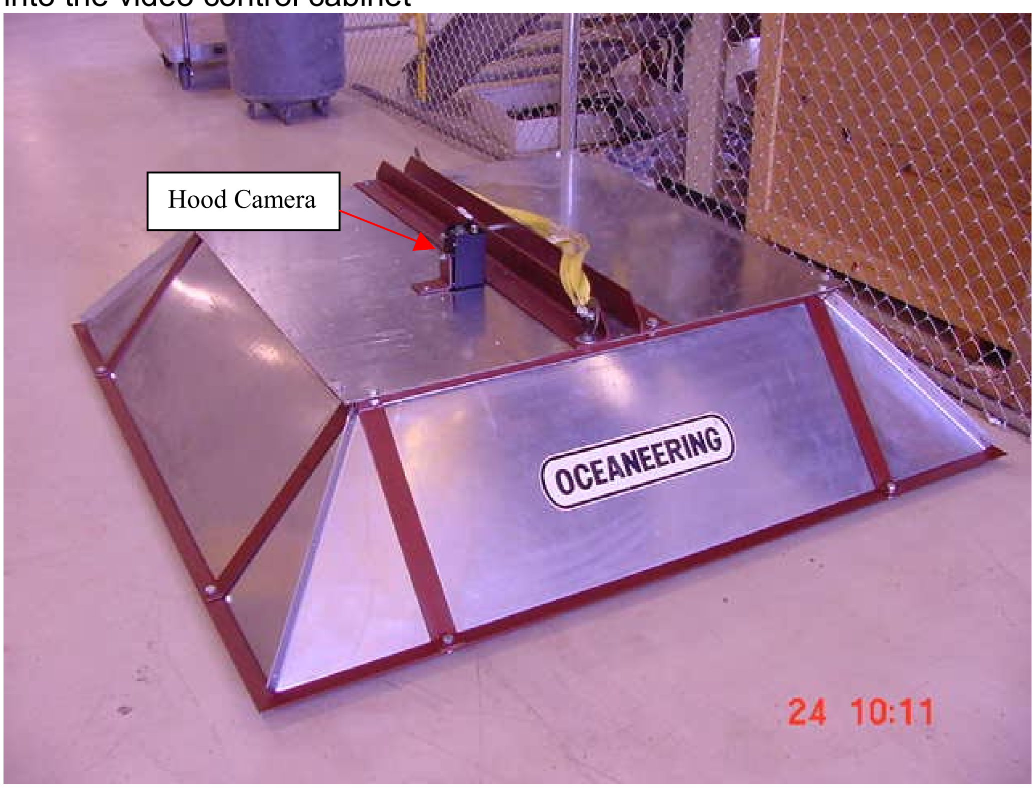



Figure 3.10.1-1 Fume Hood with camera attached

The Electromagnet assembly

The Electromagnet assembly is designed to perform the transfer of the cut piece of tower to the storage bin. The electromagnet assembly consists of three electromagnets housed in a steel shell. The Electromagnet is attached to the hood by a stanchion. The Electromagnet assembly is rated to comply with ASME standard B30.20-1999.

The Hood camera

The camera (Shown in figure 3.10.1-1) is of the same type as the cage and crawler cameras without the added Pan and Tilt capability, and will be controlled at the video control cabinet located at the control station. The purpose of the camera is to give the operator a "Birds- eye view" of the torch tip position, cutting operation, and the electromagnet assembly.

# 4 Results and Discussion

The following is a presentation of the data gathered at the demonstration. Refer to the Demonstration Log Book in Appendix A for a complete description of the progress of the demonstration and details of cutting schemes.

## 4.1 System Set Up

### 4.1.1 Personnel required for Set Up

2 "RITES" system technicians

### 4.1.2 Time required for Set Up

Elapsed time was ≈ 2.5 hours, total man hours required was ≈ 5 hours

### 4.1.3 Set up Tasks

Placing and opening control modules
Connecting control cables to Tether Management System
Connecting all systems to appropriate utility services
Exercising and testing all system functions

## 4.2 Other Considerations for Set Up

Depending on where the system is to be employed, riggers, crane operators, forklift operators may be necessary.
Time required for site electrician to install services not included.
After the system is set up and deployed it takes one (1) operator ≈ .25 hours to activate the system and test its functions.

## 4.3 System Operation

Personnel required for demonstration: one (1) system operator, one (1) crane operator.

Personnel requirements estimate for T-Plant operations: one (1) system operator, one (1) crane operator, one (1) Radiation Protection person, two (2) radworkers and one (1) rigger to assist with initial deployment of Tether Management System and cables and to connect ground leads to tower structure.

## 4.4 System Shutdown and Packaging

Shutting system down, disconnecting power and placing in a safe condition required one (1) system operator and less than 5 minutes.
Packaging the system after the cold demonstration in a suitable condition to be loaded on a transport truck required three (3) system operators and a total of ≈ 8.5 man hours

## 4.5 Production Throughput

Throughput will vary depending upon not only the type of structure to be size reduced but also the particular portion of a structure to be size reduced.

### 4.5.1 Demonstration Cutting of a horizontal “I” beam

The time required to completely severe one side of a horizontal beam was ≈ 1.5 hours. Changing the cutting plan resulted in completely severing the opposite side of the beam in ≈ 0.5 hours.
To have completely severed an additional piece would have required one additional cut (as the piece already had one severed end) and would have taken ≈ 0.5 hours.
Assumptions will be based on the cutting plan used for the second cut (0.5 hours to sever one side of a piece). See Figures 4.5.1-1, 4.5.1-2 and 4.5.1-3.

Figure 4.5.1-1  RITES Torch cuts window in a horizontal "I" beam web

Figure 4.5.1-2  Sparks erupt as the RITES Torch penetrates the steel web.

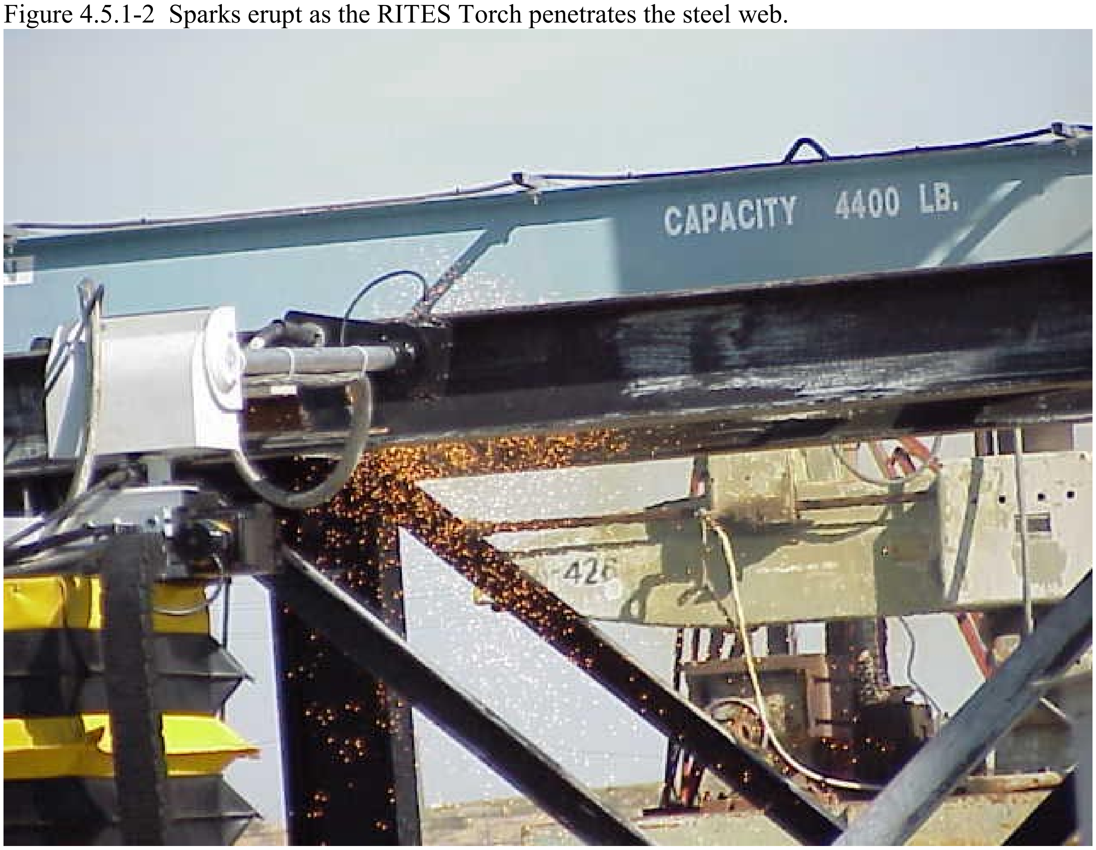


Figure 4.5.1-3 The window in the web is widened by the RITES Torch

### 4.5.2 Test Cutting of a Vertical “I” Beam

Although a vertical beam was not cut during the demonstration, system operators made several test cuts on vertical beams to validate the cutting plan and determine if any positioning difficulties existed.

As a result of the test cuts, operators have estimated that cutting a vertical beam would require approximately the same approach and time as required to cut a horizontal piece.

### 4.5.3 Demonstration Cutting of an Angled Beam

The time required to completely severe two sides of an angled beam was $\approx$ 1.0 hour. To have completely severed an additional piece would have required one additional cut (as the piece already had one severed end) and would have taken $\approx$ 0.5 hours.

| | Assume: | Assume: All Horizontal "I" Beams | Assume: All Vertical "I" Beams | Assume: All Angled Beams |
|---|---|---|---|---|
| Start Up Time | | 0.5 hours | 0.5 hours | 0.5 hours |
| Operations Time | | 7.0 hours | 7.0 hours | 7.0 hours |
| Shut Down Time | | 0.5 hours | 0.5 hours | 0.5 hours |
| Cuts Per Shift | Completely severing through one piece at one location = 1 cut | 14 | 14 | 14 |
| Pieces Per Shift | Every four pieces requires five cuts | 11-12 | 11-12 | 11-12 |
| Boxes Per Shift | Estimate | 1/2 | 1/2 | 1/2 |

Table 5.3-1 Summary of Production Throughput for a Nominal 8-hour Operational Shift

## 4.6 Camera views and work area visibility

In some positions, view of cutting area is limited or nonexistent.
No practical views of cutting area possible below ≈ 3.5 foot level
No practical view behind vertical structures or under horizontal structures.
Due to limited visibility and cutting torch positioning capability, additional cuts are required, than would otherwise be necessary, to achieve severance of piece.
View(s) into cutting surface are limited.

### 4.6.1 Functionality of Hood

Fixed distance between hood and lifting magnet precludes cutting lower sections in structure without first removing all upper sections of structure.
Residual magnetic properties, after power to electromagnet is shut off, holds small pieces not allowing them to drop in waste container.

### 4.6.2 Plasma Torch

No remote controls to adjust amps and cutting mode (normal cut, expanded cut)

# 5 Conclusions and Recommendations

## 5.1 Conclusions

The results of this Phase I program have helped determine the viability of this alternative to manual disposition of large equipment. Oceaneering Remote Intervention demonstrated the ability to adapt existing field-hardened equipment to perform remote size reduction, in-situ, in a safe, effective manner. The integration of these technologies provides a synergistic effect.

The test results documented that the RITES is capable of:

- Removing personnel from the work area during cutting.
- Reducing total man-rem.
- Remote volume reduction of TRU waste without the generation of secondary waste.
- Deployment of commercially available equipment.

To fully assess the ability to limit the spread of contamination was not considered during this demonstration due to the absence of a vacuum source.

This project demonstrated that on its first use, the RITES equipment provided an effective and innovative approach to remote size-reduction of a steel structure, similar to the PUREX T-L2 and T-J4 towers; and is applicable to remote size-reduction of other large equipment. Incorporation of the following improvements and enhancements, as well as implementation by project operators, will provide a versatile application for TRU waste processing.

## 5.2 Recommendations

### 5.2.1 Operational Improvements

Equipment Improvements and Enhancements

- Add a 7-axis, kinematically redundant manipulator. Reach should extend ≈ 50 to 60 inches beyond plane of vehicle. Continuous working payload, at full extension, should be a minimum of 30 to 40 pounds. Insure manipulator is robust and designed for continuous heavy duty. Manipulator should be capable of withstanding shocks and bumps.
- Add two (2) fixed position cameras (pencil type). Attach to plasma torch tip and position to focus on cutting area. One (1) camera to view in normal light. One (1) camera outfitted with “welders” lens (filter) to enable operator to view plasma arc during cutting.
- Explore concept of adding a pneumatically operated “punch” to dislodge slag.

- Consider positioning vehicle pan & tilt camera on a telescoping mount.
- Maintain flexibility of torch mounting device.
- Evaluate mounting manipulator on mechanical slide assembly that provides both X and Y linear motion.
- Explore methods of stabilizing lift table on vehicle. Vehicle tilts as linear slide moves toward outboard position. Makes controlling cuts very difficult. Point may be mute depending on function and dexterity of manipulator.
- Add remote control device to choose both “normal” and “expanded” cut mode on plasma machine.
- Modify vehicle ramp on Tether Management Cage. No more than 20% incline. Consider eliminating incline all together.
- Angle vehicle tether “stinger” upward.
- Consider replacing tracks with pneumatic tires and wheels. Tracks and a variety of wheel types can be made interchangeable.
- Controls should be made more ergonomically efficient and operator friendly.
- Position monitors at operator eye level.
- Extend working area between top of lifting magnetic and bottom of exhaust hood
- Consider replacing magnet with mechanical lifting device for non-ferrous metals.
- Consider making distance between hood and lifting device adjustable.
- Reposition hood camera for better view of cutting area. Consider changing hood camera to pan & tilt type.
- Explore additional tools that can be attached to vehicle.

### 5.2.2 Optional Uses of System

- Remote radiation monitoring including dose rates, characterization, air sampling, hot spot identification and sample collection.
- Work group monitoring (add two way microphones)
- Hot” object retrieval and “hot” filter change out.
- DAW and LSA sorting and repackaging
- Valve manipulation in “hot” areas
- Slurry platform for contaminated liquids
- Remote inspections
- Decontamination platform
- Deployment of specialist tooling
  - Vacuum head
  - High-pressure spray nozzles
  - Slurry wands
  - Spray head for strippable coatings
- FME retrieval
- Vehicle can be made submersible for work in lagoons